Turbidimeter Measurement of Suspended Sediment

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of Suspended Sediment

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ABSTRACT

Study of a turbidimeter to determine its accuracy in predicting suspended sediment concentrations showed maximum errors of -184 percent at one gaging station, 261 percent at another, and average prediction errors of 31 and 25 percent. Poor correlation was caused by changes in particle-size distribution of the suspended sediment; the turbidimeter responded less to larger sediment sizes. Although turbidimeters are generally unsuitable for determining total concentrations, findings indicate that they may be useful in cases involving fine sediments: for determining total load where the transport is predominantly fine material, where only the concentration of fine load is desired, or in reservoir sediment research where only fine material reaches the main body of water. Index terms: pollutants, sediment transport, sedimentation, turbidimeters, water pollution, water quality.

INTRODUCTION

Because of concern about environmental pollution, collection of streamflow samples for sediment concentration analyses has greatly increased. Sediment is itself a pollutant, and for much of the United States, such chemical pollutants as phosphorus, organic nitrogen, pesticides, and heavy metals are mainly transported attached to sediment particles. Much effort has been expended to develop instruments to measure sediment concentrations in streams automatically, and replace the slower and costlier conventional procedure of collecting streamflow samples and determining sediment content in a laboratory. So far, none of these instruments has been successful enough to warrant their widespread use.

Turbidity measurement is a technique that has been investigated often, and some researchers (Brown and Ritter 1971, Kunkle and Comer 1971, Grassy 1943) have suggested that it may be useful for obtaining approximate sediment data, extending sediment data, or reducing sediment data collection costs. This report describes results from field and laboratory tests with a turbidimeter at the Southern Great Plains Research Watershed, Science and Education Administration, U.S. Department of Agriculture, Chickasha, Okla.

EQUIPMENT AND PROCEDURE

The turbidimeter used was a Hach Chemical Co. model 1031, in which light passes through a thin falling stream of the fluid being tested before striking a photocell. Photocell output was recorded with a strip-chart-recording microammeter. Because antecedent light and ambient temperature affected the photocell, the light source was left on continuously, and the recording microammeter was actuated when a runoff event occurred. Turbidimeter readings were scaled from a full-light reading, and represent the light ab-
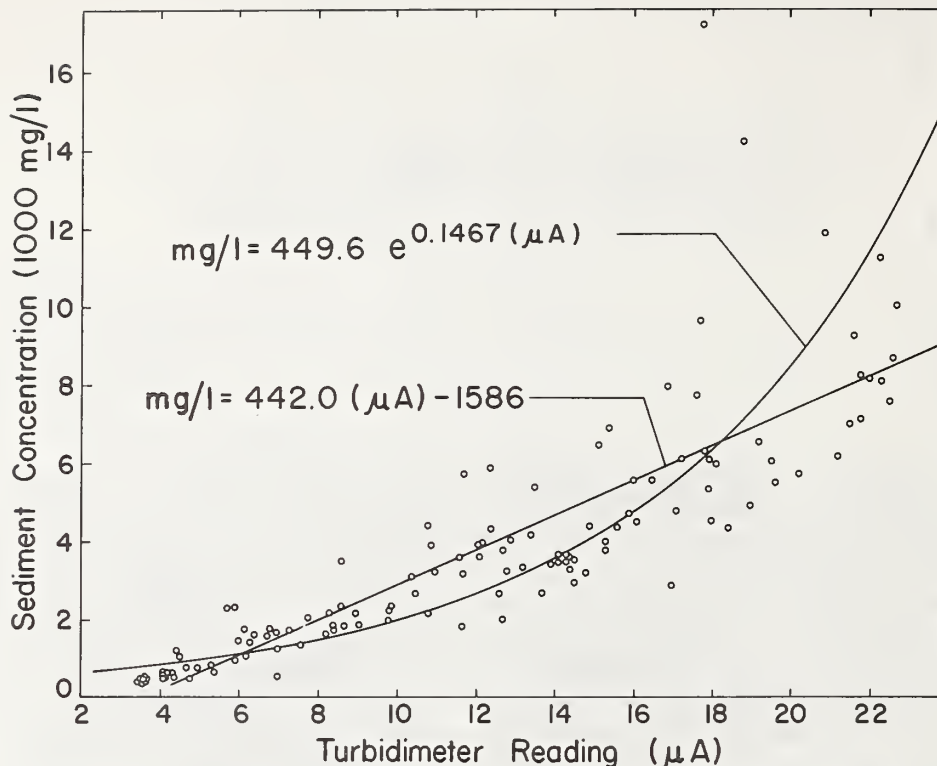
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FIGURE 1.—Sediment concentrations versus turbidimeter readings at East Bitter Creek.

sorbed by the water-sediment mixture. These readings were subjected to correlation analysis.

Turbidimeter readings and sediment concentration data were collected from 1968 through 1970 at two gaged tributaries of the Washita River in southwest Oklahoma. The instrument was first installed at East Bitter Creek (drainage area 91 square kilometers) in conjunction with a US PS–66A pumping-type sediment sampler. A T was installed in the pumping line so that part of the pumping sampler flow was diverted through the turbidimeter at each sampling and sediment sampling and turbidimeter reading were simultaneous. Samples of stormflow were collected every 30 minutes during stream rises and at either 1- or 2.5-hour intervals on recessions.

In 1969, the turbidimeter was moved to West Bitter Creek (drainage area 157 square kilometers). The experimental setup was like that at East Bitter Creek, except that a separate pump was used for the turbidimeter rather than using part of the flow from the sediment sampler. Samples were collected when the streamflow rose or fell at least 9.1 centimeters, and turbidimeter readings were taken simultaneously.

A total of 125 and 127 data pairs were collected at East and West Bitter Creek. Fifty-seven of the East Bitter Creek sediment samples and 71 of the West Bitter Creek samples were sieved for sand content (greater than 62 micrometers).

Because the sediment at West Bitter Creek was found to have about twice the light-absorbing capacity of East Bitter Creek sediment, another turbidimeter nozzle was installed to reduce the thickness of the falling stream from 0.32 to 0.16 centimeters and keep the light transmitted within the photocell's range of sensitivity and away from the "blind" region near total light extinction.

In addition to normal samples and turbidimeter readings, eleven 3.5-liter streamflow samples were taken during a flow event at West Bitter Creek on September 22 and 23, 1970. The samples were taken to the laboratory, fractionated by sedimentation and decantation (using Stoke's law) at six arbitrarily selected sizes, and each decanted fraction was measured with the turbidimeter. At each fractionation, both parts of the sample were retained, so that they could be recomposited for successive fractionations and turbidimeter measurements.
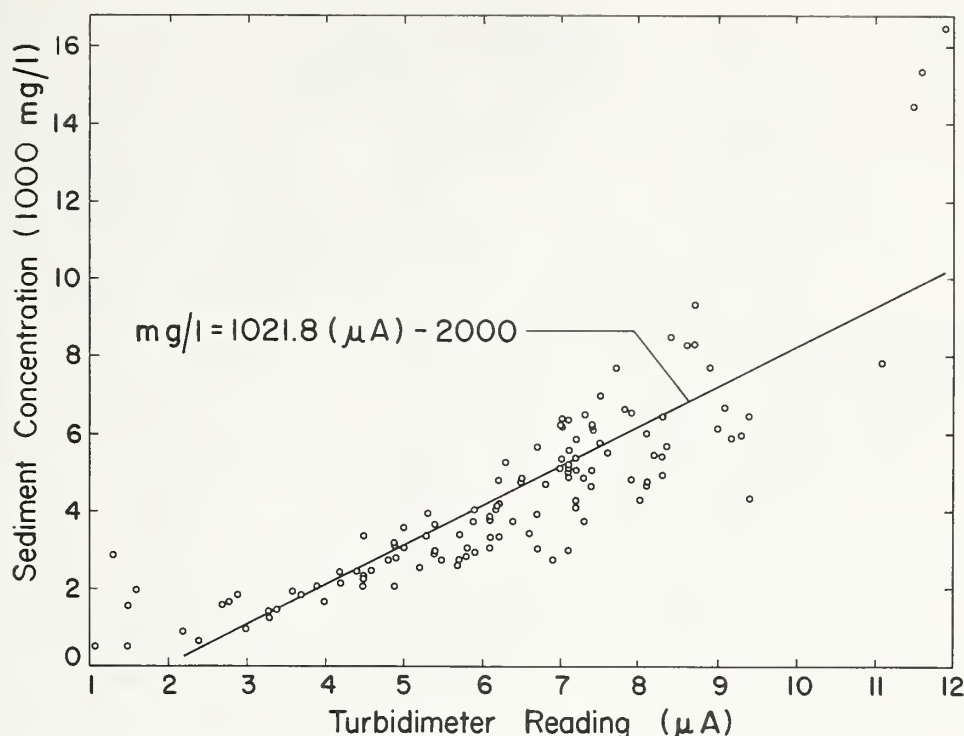
FIGURE 2.—Sediment concentrations versus turbidimeter readings at West Bitter Creek.

After the final measurement, each sample was again recomposited and particle-size distribution was analyzed by wet sieving and the pipette procedure. These analyses were made with the native stream water and no dispersant, leaving the silt and clay particles naturally aggregated. Analyses made in this manner should be more meaningful, because they simulate the field conditions in which turbidimeters would probably be used.

Concentration was determined for each decanted fraction by multiplying its percentage of total sample weight (obtained from the particle-size distribution) by the respective total concentration. Total concentrations were determined by analyzing the 350-milliliter pumping-sampler samples.

ANALYSES AND FINDINGS

Sediment concentrations ranged from 405 to 17,200 milligrams per liter at East Bitter Creek and from 522 to 16,500 milligrams per liter at West Bitter Creek. When East Bitter Creek sediment concentrations were plotted against turbidimeter readings (fig. 1), data point scatter was

great, especially at higher turbidimeter readings. A linear regression analysis gave a coefficient of determination (r^2) of 0.71 (readings explained 71 percent of the variation in the concentration data). The maximum error of the predicted concentrations was -184 percent, and the average of all errors was 31 percent.

Because the data seemed slightly curvilinear (fig. 1), a least-squares regression was run using logarithms of sediment concentrations against the microammeter readings, and a small improvement in accuracy resulted (+103 percent maximum error and 30 percent average error).

West Bitter Creek data (fig. 2) also was considerably scattered. A linear regression analysis gave an r^2 of 0.70, a maximum predicted error of 261 percent, and an average error of 25 percent.

For each of the 3.5-liter samples, turbidimeter readings were plotted against concentrations representing particles finer than the sizes indicated (fig. 3). The turbidimeter-reading-to-concentration response (slope of the bar graph segments) for each size range is essentially the same as if the samples were separated into seven size-range fractions and a turbidimeter reading
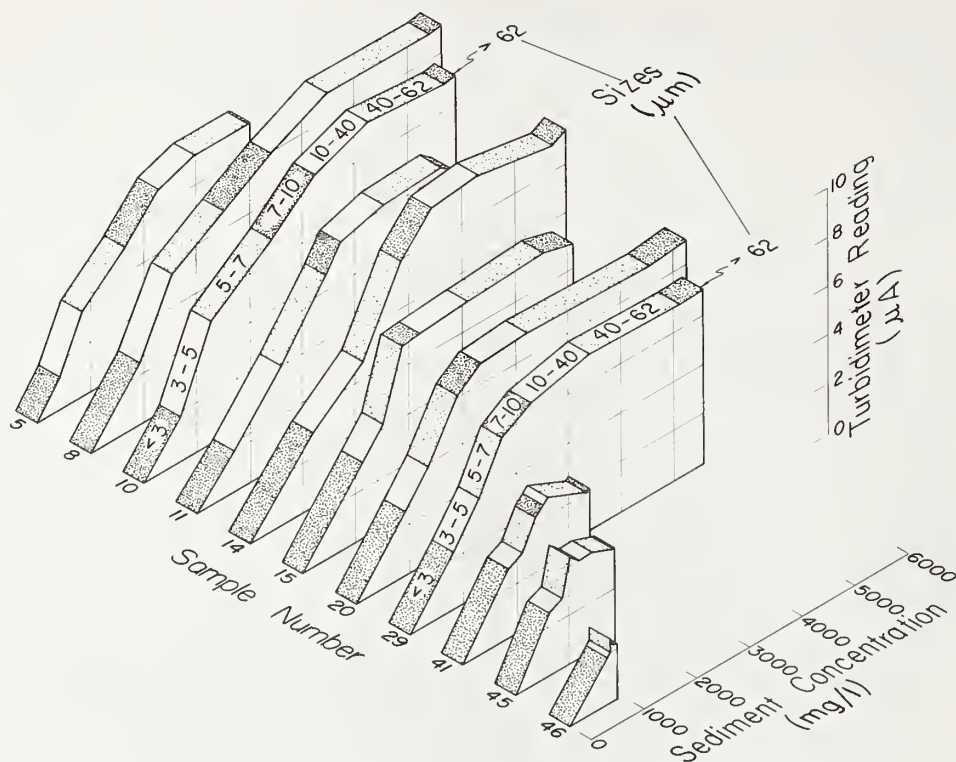
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FIGURE 3.—Turbidimeter response to various sediment-size fractions.

taken on each fraction. The relative response can be visually compared from sample to sample for a size range, and from size range to size range for any given sample. Inconsistent slopes within a range and the occasional decreasing slopes may have been caused by prior sample contamination, such as sediment residue in the circulating pump and lines.

An analysis of variance (1 percent level) of the incremental slopes, expressed as microamperes times liters per milligram (μA·l/mg) indicated a significant difference among sizes. A multiple-range test for the mean μA·l/mg of size ranges is shown in table 1. The lower the mean μA·l/mg, the less sensitive the turbidimeter is to changes in concentration. The mean μA·l/mg for the four size ranges finer than 10 micrometers did not differ significantly, and the slopes for these sizes are steeper than for the other size ranges. The mean μA·l/mg for size ranges 7 to 10, 10 to 40, and >62 micrometers did not differ significantly and have flatter slopes than the smaller sizes. Mean slopes of size ranges 10 to 40, 40 to 62, and >62 micrometers also did not differ significantly and had the lowest average mean μA·l/mg.

CONCLUSIONS

The turbidimeter's accuracy in measuring suspended-sediment concentrations was not good, and if the turbidimeter calibration curve developed with the concentration data from the pumping sediment sampler were used to predict concentrations for periods other than those when the data were collected, maximum and average errors would undoubtedly increase. The turbidimeter was less responsive to sediment with large

Table 1.—Duncan's multiple-range test (1% level) of mean μA·l/mg for various particle-size fractions[1]

Particle-size fraction (μm)	Mean (μA·l/mg)
<3	0.00265a
3–5	.00355a
5–7	.00350a
7–10	.00215ab
10–40	.0059bc
40–62	-.00010c
>62	.00026bc

[1]Means followed by the same letter do not differ significantly at the 1% level.

particles than to that with smaller particles. For the 10- to 40-micrometer particles, response was only about one-sixth that for the three smaller sizes. Response for the two largest sizes (40 to 62 micrometers and >62 micrometers) were smallest of all. This difference in response probably caused the poor correlation between the turbidimeter and total concentration data. In suspended sediments containing fine particles a turbidimeter will hardly detect large concentration changes in coarse fractions.

The instrument is generally unsatisfactory for accurate suspended-sediment data, but could be useful where only approximations of transport data are needed. The consistent relation between turbidity and concentration for finer sediment sizes suggests that turbidimeters may have use in cases involving fine sediments. It could be used (1) to determine total load where the transport is predominantly fine material, (2) where only the concentration of fine load is desired, or (3) in reservoir sediment research where only the fine material reaches the main body of water. When it is used, a turbidity-versus-concentration calibration must be made at each streamflow site or reservoir. Where sediment transport data is collected solely with manual samplers, turbidimeters could also be used to guide interpolation and extrapolation of manual data points.

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